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TANTALUM-TUNGSTEN ALLOY

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5 Claims

ABSTRACT OF THE DISCLOSURE

A novel alloy is disclosed consisting essentially of from 1.5 to 3.5 weight percent of tungsten, the balance of the alloy being essentially tantalum. Optionally, the alloy contains from 0.05 to 0.5 weight percent of columbium. These alloys have improved strength when compared with pure tantalum, yet they are cold workable in conventional equipment for cold-working tantalum, unlike the known tantalum-tungsten alloys having higher concentrations of tungsten. Also, the alloys disclosed herein show improved corrosion resistance over pure tantalum and the known tantalum-tungsten alloys having a higher tungsten concentration.

BACKGROUND OF THE INVENTION

Tantalum and its alloys are commonly used in environments in which their superior corrosion resistance can be relied upon to provide long lived components such as bayonet heaters and heat exchangers exposed to corrosive solutions such as sulfuric acid, hydrochloric acid, and nitric acid.

Pure tantalum is often cold worked, i.e. at temperatures below the point (about 1000° F.) where significant oxidation can occur on the tantalum in the presence of air. This cold working generally is performed by machinery such as a 4,000 pound steam hammer, to prepare shaped tantalum articles for commercial use.

In some applications in which the tantalum is required to endure high stress or pressure at elevated temperatures of about 400° F. or above, the strength properties of pure tantalum are marginal, and a stronger material is frequently needed, such as in chemical process equipment, especially in the forms of tubing and sheet.

It is known to add tungsten, e.g. about 5 to 10 weight percent, to tantalum to produce alloys having a higher tensile strength than pure tantalum, but large pieces of such alloys (e.g. having dimensions greater than 2 or 3 inches in thickness) are too hard to be cold worked on the commercial equipment which is generally used to cold work pure tantalum. Thus, when a tantalum alloy of higher strength than pure tantalum is needed to fabricate a part of larger size, manufacturers have been previously forced to either hot work tantalum-tungsten alloys in an air atmosphere, which causes degradation in the materials because of embrittlement of the surface layers due to diffusion of oxygen and nitrogen into the metal, or to cold-work the alloys in extremely heavy and expensive equipment.

This application relates to tantalum-tungsten alloys having substantially higher tensile strength than pure tantalum, but which are cold workable in equipment conventionally used to cold work pure tantalum. Furthermore, the alloys of this invention exhibit improved corrosion resistance to acids when compared with either pure tantalum or the known tantalum-tungsten alloys of higher tungsten concentration.

SUMMARY OF THE INVENTION

This application relates to a single phase, cold workable alloy having high corrosion resistance and consisting

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essentially of from 1.5 to 3.5 weight percent of tungsten, the balance of said alloy being essentially tantalum.

Preferably, the above alloy also contains from about 0.05 to 0.5 weight percent of columbium (also known as niobium). It is believed that the presence of such a small amount of columbium aids in reduction of the grain size in the alloy, resulting in a material having better physical properties.

The capability of an alloy to be cold worked can be looked upon as a function of the difference between its yield strength (the amount of stress required to make a bar of the alloy permanently deform or stretch a distance of 0.2 percent of the length of the bar) and its ultimate tensile strength (the amount of stress required to break the bar of alloy). By application of stresses having a magnitude ranging between the value of these two tensile strengths, it is possible to form or shape a piece of metal into a desired configuration without breaking it.

The alloys of this invention typically have a yield tensile strength at ambient temperatures of at least about 30,000 p.s.i. and an ultimate tensile strength at ambient temperatures of at least about 46,000 p.s.i. The wide gap of about 16,000 p.s.i. between the two tensile strengths indicates that the alloys of this invention are readily cold workable by rolling or forging into strong metal sheeting, metal cups, or other structures as desired.

At ambient temperatures, the yield tensile strength of an alloy of this invention containing 2.5 weight percent of tungsten is about 35,000 p.s.i. while the ultimate tensile strength is about 53,000 p.s.i. The difference between these two values is about 18,000 p.s.i., which is about 35 percent of the value of the ultimate tensile strength.

By comparison, a tantalum-tungsten alloy containing 10 weight percent of tungsten has, at ambient temperatures, a yield tensile strength of about 89,000 p.s.i. and an ultimate tensile strength of about 96,000 p.s.i. This material is too hard for large pieces to be cold worked in conventional equipment for working pure tantalum. Also, the difference between these two tensile strengths is only about 7,000 p.s.i., or less than 10 percent of the ultimate tensile strength. This compares with the 16,000 p.s.i. difference between the two tensile strengths of the alloys of this invention.

The above principles also hold true at temperatures up to the maximum cold working temperatures. For example, at 600° C. (1040° F.), an alloy of this invention containing 2.5 weight percent of tungsten has a yield tensile strength of about 15,000 p.s.i. and an ultimate tensile strength of about 34,000 p.s.i. The difference between these two tensile strengths is about 19,000 p.s.i., more than one half the value of the ultimate tensile strength at that temperature. Thus it can be seen that the gap between yield strength and ultimate tensile strength does not diminish, although both strength values naturally drop on heating.

A wide spread between the yield tensile strength and ultimate tensile strength of a metal is particularly important because a piece of metal being worked is subjected to different magnitudes of stress at different portions of the metal. In order for a metal object to be successfully shaped each portion of the object must be subjected to stresses which are above the yield tensile strength so that each portion of the metal object can be deformed, but the stresses on each portion must be below the ultimate tensile strength so that cracks do not form. Since the magnitude of the stress forces can vary considerably throughout the various portions of the metal object to be shaped, a wide range between the yield and ultimate tensile strength is important.

When the prior tantalum-tungsten alloys of higher tungsten content are heated, their tensile strength also

drops, but not to such a degree that they can be cold worked in conventional machinery for working tantalum. Also, the differences between their yield tensile strengths and ultimate tensile strengths are much lower at high temperatures than in the alloys of this invention. This causes such alloys to be less ductile than the alloys of this invention.

Alloys of this invention which have optimum cold working characteristics and which show optimum corrosion resistance to acids are obtained when the tungsten content is from about 2 to 3 weight percent. These alloys have yield tensile strengths ranging from about 32,000 to 38,000 p.s.i. and ultimate tensile strengths from about 48,000 to 55,000 p.s.i., at ambient temperatures. They combine the advantages of substantially greater strength than pure tantalum, which has a yield tensile strength of about 24,000 p.s.i. and an ultimate tensile strength of about 37,000 p.s.i. at ambient temperatures, with the capability of being cold worked on the conventional machinery used for cold working pure tantalum. In addition to this, and surprisingly, the corrosion resistance of these alloys exceeds that of pure tantalum and any other known tantalum-tungsten alloy.

DESCRIPTION OF SPECIFIC EMBODIMENT

The following example illustrates a typical alloy of this invention having the above desirable characteristics, and should not be construed as limiting this invention, which is defined in the claims.

A metal ingot having the composition described below was produced by conventionally electron beam melting blends of tantalum, tungsten, and columbium powders. The ingot was re-melted several times by an electron beam to achieve an essentially homogeneous alloy of one phase.

After melting, the alloy consisted primarily of tantalum (about 97.74 weight percent), but contained other ingredients as shown below in the following proportions, taken as an average of the values obtained from two analyses at the two ends of the ingot:

tungsten—2.5 wt. percent
columbium—0.08 wt. percent
carbon—less than 10 p.p.m.*
nitrogen—less than 15 p.p.m.
oxygen—33 p.p.m.
hydrogen—less than 5 p.p.m.
molybdenum—less than 5 p.p.m.
cobalt—less than 5 p.p.m.
iron—10 p.p.m.
vanadium—less than 5 p.p.m.
titanium—less than 5 p.p.m.
zirconium—less than 5 p.p.m.
silicon—less than 5 p.p.m.
magnesium—less than 5 p.p.m.
tin—less than 5 p.p.m.
copper—less than 5 p.p.m.
nickel—less than 5 p.p.m.
aluminum—less than 5 p.p.m.
calcium—less than 5 p.p.m.
manganese—less than 5 p.p.m.
chromium—10 p.p.m.

* Parts per million.

The above metal ingot, having the shape of a solid cylindrical rod seven inches in diameter, was forged on a 4,000 lb. steam hammer into a long rectangular bar six inches wide and two inches high. The temperature of the ingot during forging was about 900° F., which is below the temperature at which significant oxidation of the ingot takes place in air.

A cut portion of the bar of alloy was then repeatedly cold rolled, with an intermediate anneal at about 1400° C. (2550° F.) for 60 minutes, to a ¼ inch plate. Analysis of the cut portion of the bar used showed it to contain about 2.7 weight percent of tungsten and 0.16 weight

percent of columbium, the balance being essentially tantalum.

The ¼ inch plate of alloy was then annealed again at 1250° C. (2280° F.) for 60 minutes, and rolled to a thickness of 0.02 inch. Following this, it was annealed at 1200° C. (2190° F.) for 60 minutes to achieve 100 percent recrystallization. The grains were of small size (ASTM grain size No. 7½) compared with a similarly processed sheet of pure tantalum which had a larger grain size (ASTM grain size No. 4½ or 5).

The rolled sheet of alloy showed excellent bend ductility and weldability. Welded and re-drawn tubing can be processed from the alloy sheet without difficulty.

The recrystallized 0.02 inch sheet of alloy was tested for its yield tensile strength and its ultimate tensile strength (using those terms as defined above) at 200° C. (392° F.). The elongation of the sheet at its break point was also determined as a percentage of the length of the sheet in a 2-inch gage length. As a control, a 0.02 inch thick sheet of recrystallized tantalum was similarly tested. The results were:

Material	Yield tensile strength ¹	Ultimate tensile strength (p.s.i.)	Elongation ²
The above tantalum-tungsten alloy.....	28,800	45,500	34
Tantalum (100%).....	15,300	34,900	39

¹ 0.2 percent offset, p.s.i.

² Percent in 2-inch gage length.

At ambient temperatures, a 0.02 inch thick sheet of the same tungsten-containing alloy was found to have a yield tensile strength of 34,200 p.s.i., an ultimate tensile strength of 53,000 p.s.i., and an elongation of 42 percent.

Sheets of the above, fully recrystallized tungsten containing alloy having dimensions of 5½ inches, length, ½ inch width, and 0.010 to 0.012 inch thickness were immersed in sulfuric acid at a temperature of 200° C. (392° F.) for a total of 32 days.

The weight loss of the tantalum-tungsten alloy sheet was determined by comparing the initial weight of the sheet with the weight of the dried sheet after the 32 days of immersion. This weight loss figure was then calculated as a linear rate of corrosion of the alloy sheet by the sulfuric acid, expressed in inches per year. A similar sheet of pure tantalum was immersed in the same bath of sulfuric acid at 200° C. (392° F.) for 32 days, and the corrosion rate measured in terms of inches per year.

The corrosion rate of the above tantalum-tungsten alloy was determined to be 0.00115 inch per year, while the corrosion rate of pure tantalum was determined to be 0.00224 inch per year.

The above test was repeated on another sheet of the above tantalum-tungsten alloy having the above dimensions, while a similar sheet of an alloy containing 90 weight percent of tantalum and 10 weight percent of tungsten was also immersed in the same bath at a temperature of 200° C. (392° F.). At the end of 13 days the test was discontinued and the corrosion rates calculated. The alloy of this invention containing about 2.7 weight percent of tungsten had a corrosion rate of 0.00124 inch per year while the alloy containing 10 weight percent of tungsten had a corrosion rate of 0.00198 inch per year.

The superiority of the above alloy containing about 2.7 weight percent of tungsten was also determined by immersing strips of pure tantalum and the above described alloy in 37 percent hydrochloric acid at 100° C. (212° F.) for 24 hours. The corrosion rates calculated from this test were 0.0009 inch per year for the tantalum-tungsten alloy containing about 2.7 weight percent of tantalum, and 0.0016 inch per year for the pure tantalum.

Thus it can be seen that the alloys of this invention have superior corrosion resistance over both pure tantalum and a tantalum alloy having 10 weight percent of tungsten.

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From the foregoing, it will be observed that numerous variations and modifications may be effected without departing from the true spirit and scope of the novel concept of the invention. It is, of course, intended to cover by the appended claims all such modifications as fall within the scope of the claims.

What is claimed is:

1. A single phase, cold workable alloy having high corrosion resistance and consisting of from 2 to 3 weight percent of tungsten, from 0.05 to 0.5 weight percent of columbium added as grain refiner, the balance of said alloy being tantalum and minor impurities, and characterized by a yield tensile strength at ambient temperatures of at least 30,000 p.s.i. and an average corrosion rate expressed in terms of inches per year of about one-half of the corrosion rate of unalloyed tantalum when exposed to concentrated sulfuric acid at a temperature of no more than about 200° C. for a period of about 30 days.

2. The alloy of claim 1 consisting essentially of about 2.7 weight percent of tungsten and about 0.16 weight percent of columbium, the balance of said alloy being essentially tantalum.

3. The alloy of claim 1 which has, at ambient temperatures, a yield tensile strength at ambient temperatures of about 35,000 p.s.i., and an ultimate tensile strength of about 53,000 p.s.i.

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4. The alloy of claim 1 wherein the average corrosion rate is no more than about 0.00124 inch per year.

5. The alloy of claim 1 wherein the average corrosion rate is between about 0.00115 and about 0.00124 inch per year.

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